NANOTECHNOLOGY

Patent for Fullerenes (example "Buckyballs" see http://www.jcrystal.com/steffenweber/gallery/Fullerenes/Fullerenes.html) Production:

3% Product to 97% Waste

POLLUTION PREVENTION

- *Source Reduction*
- *Recycling and Reuse*
- *Treatment*
- *Disposal*

"Small Is Different: Energetic, Structural, Thermal, And Mechanical Properties Of Passivated Nanocluster Assemblies"

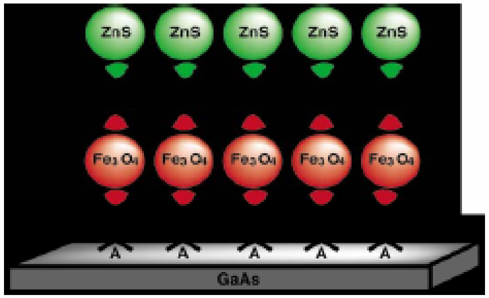
By Uzi Landman and W. D. Luedtke

In **The Royal Society of Chemistry** (2003) **125:** 1-22.

Characterization and elucidation of size-evolutionary patterns of the properties of finite materials aggregates exhibiting ***discrete quantized energy level spectra and specific structures and morphologies, investigations of*** ***unique properties*** of finite-size materials clusters, and studies of the nature of the evolution from the molecular and cluster regimes to the bulk phase, are among the major challenges of modern materials science, and as such these issues have been the subject of intensive research endeavors. These investigations include explorations of structural, electronic, thermodynamic, spectroscopic, and chemical properties of isolated clusters and their assemblies. Nanophase materials built through the assembly of nanometer-scale units into ordered superlattices offer exciting perspectives as **novel materials** whose ***optical, electronic, magnetic, transport, mechanical and thermodynamic properties*** may be controlled by the selection of the composition and sizes of the building-block units. Such diversity and tunability suggests potential utilization of these materials as components in future nanoscale-based electronic, optoelectronic, and sensor technologies.

Scales: Expanding the limits of knowledge and action

Nanoworld - natural threshold
for behavior, performance,
unity, bio-inert, manufacturability



1 to 100 nm

~ 1 m
Human scale

Outer space

Over 10,000 km

10^{-7}

10^{7}

Smallest Known Size

Largest Known Size

10^{-27}

10^{27}

M.C. Roco, 10/03/05

M.C. Roco (October 3, 2005)
"Nanotechology"

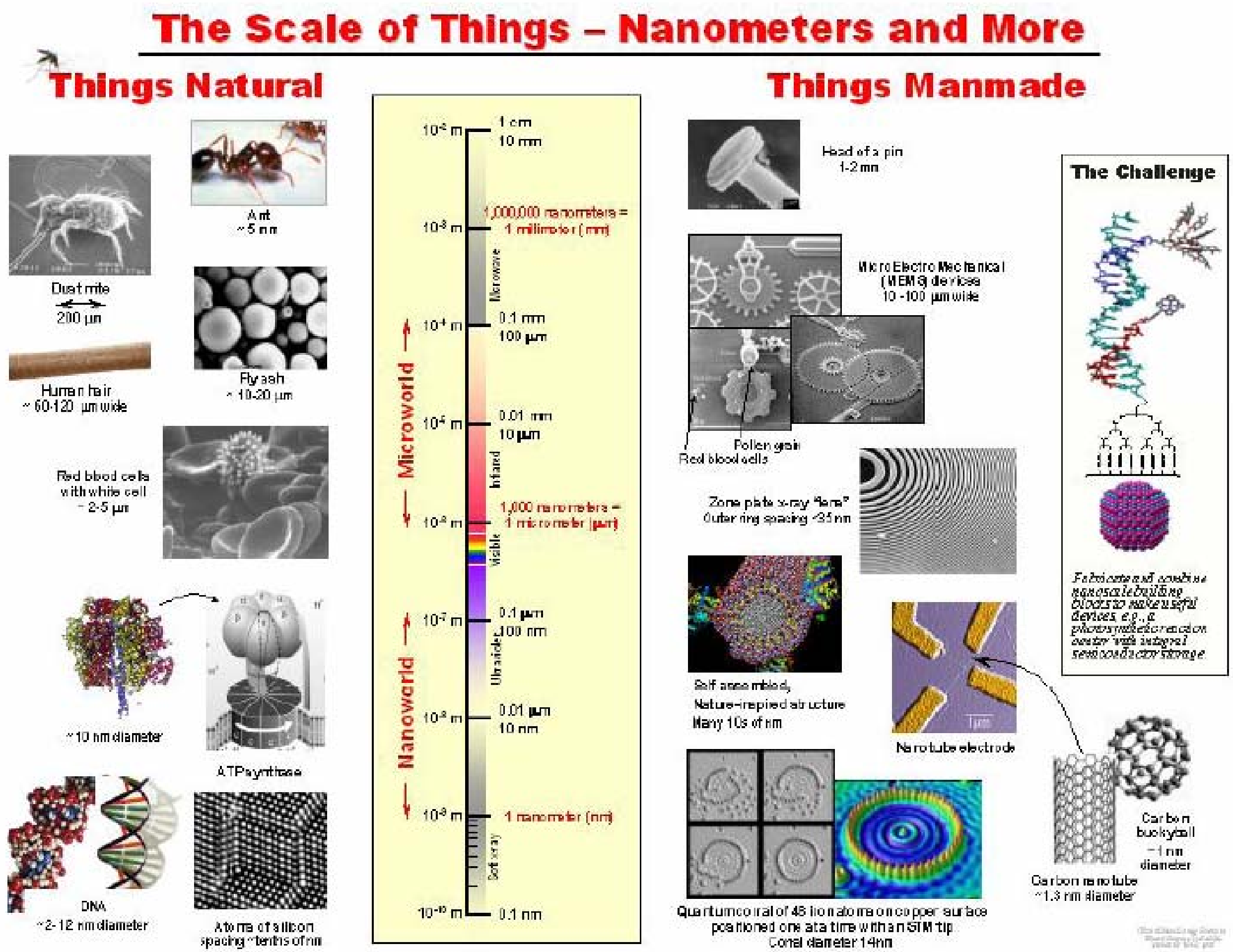
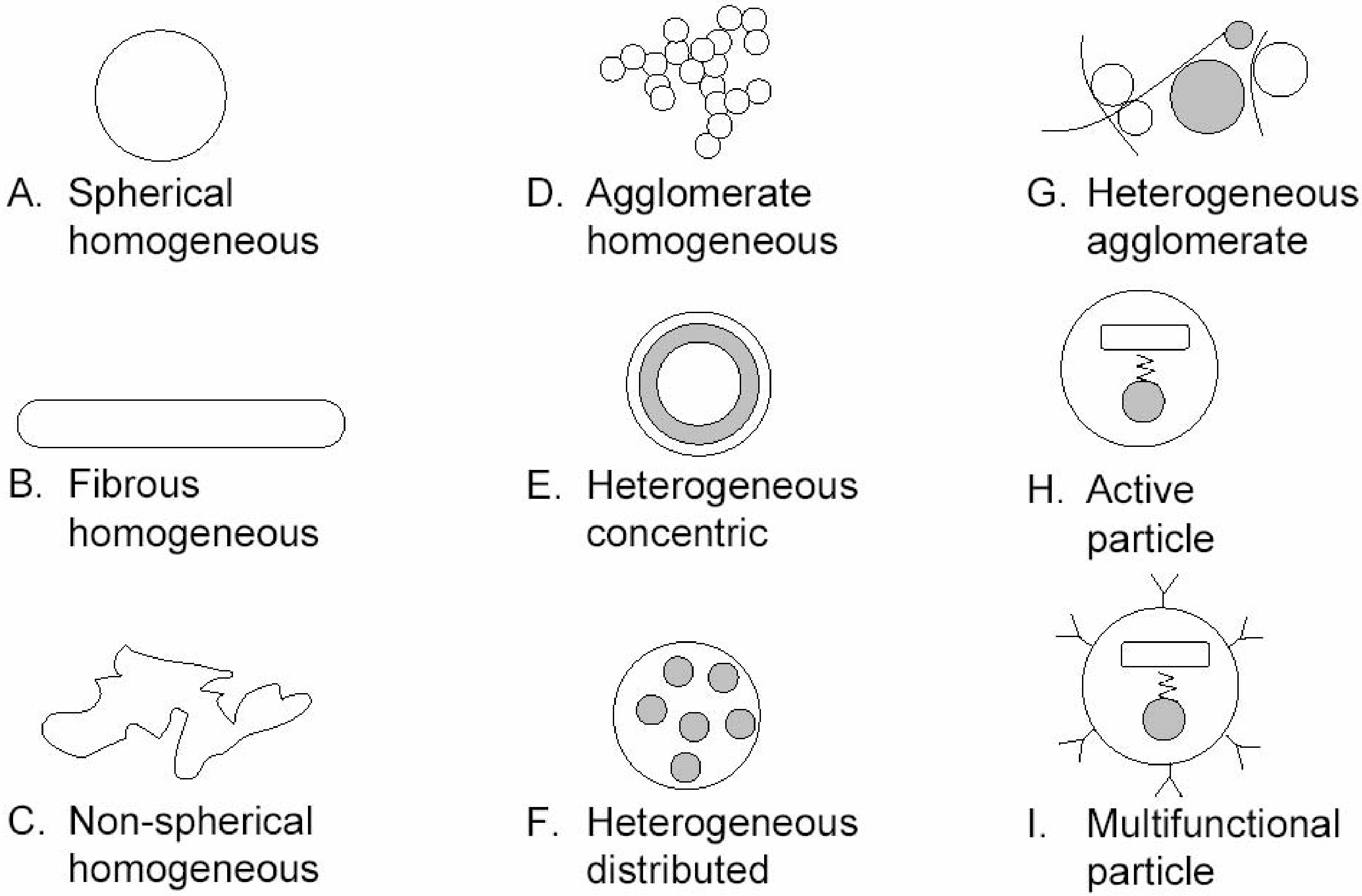


Figure 1. Diagram indicating relative scale of nano-sized objects. From NNI website, courtesy Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy

US EPA - http://www.epa.gov/osa/pdfs/EPA_nanotechnology_white_paper_external_review_draft_12-02-2005.pdf

Particle Categories

Classes of engineered nanoparticles



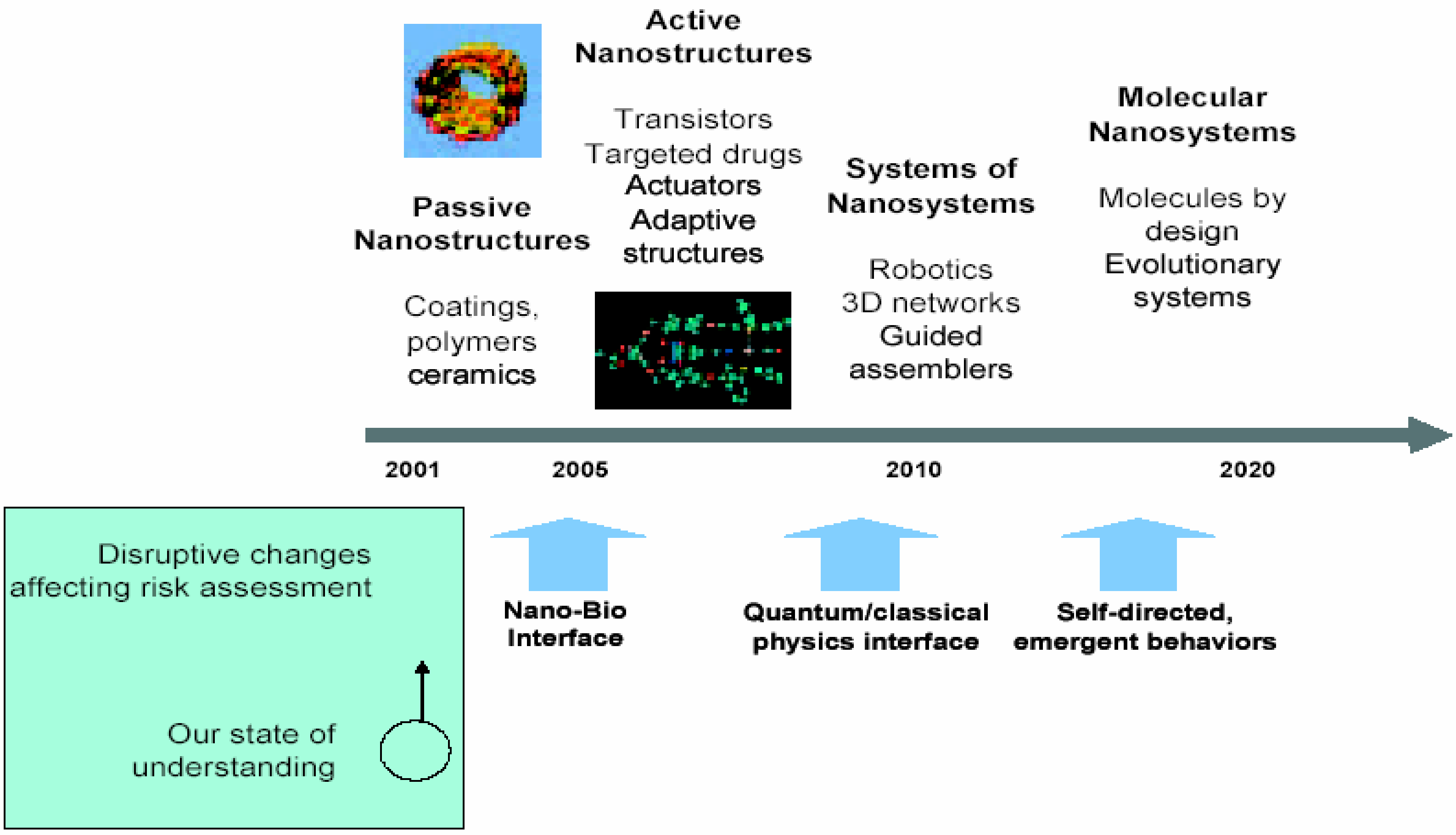
Aitken and Maynard, in preparation

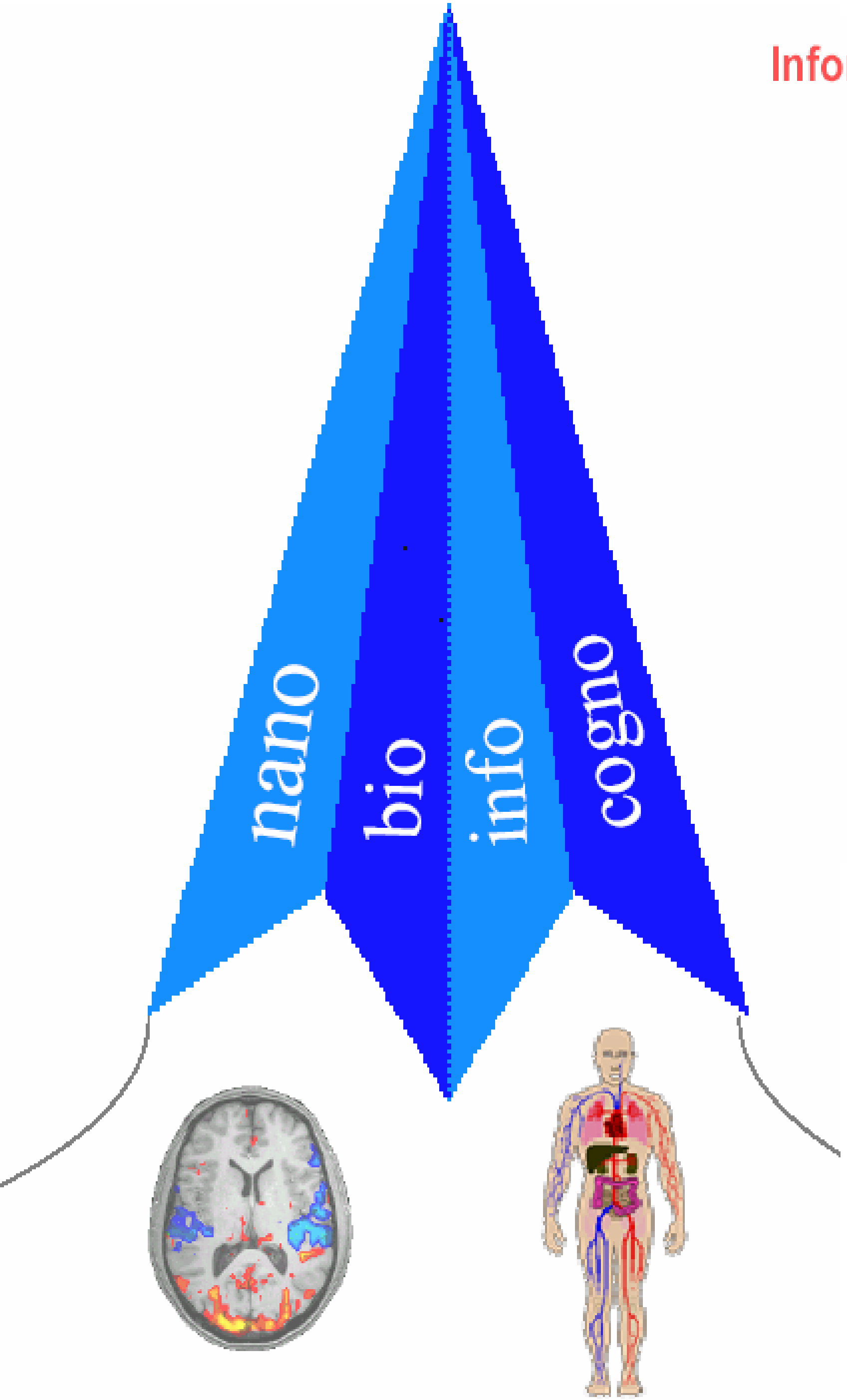
(not necessarily inclusive)

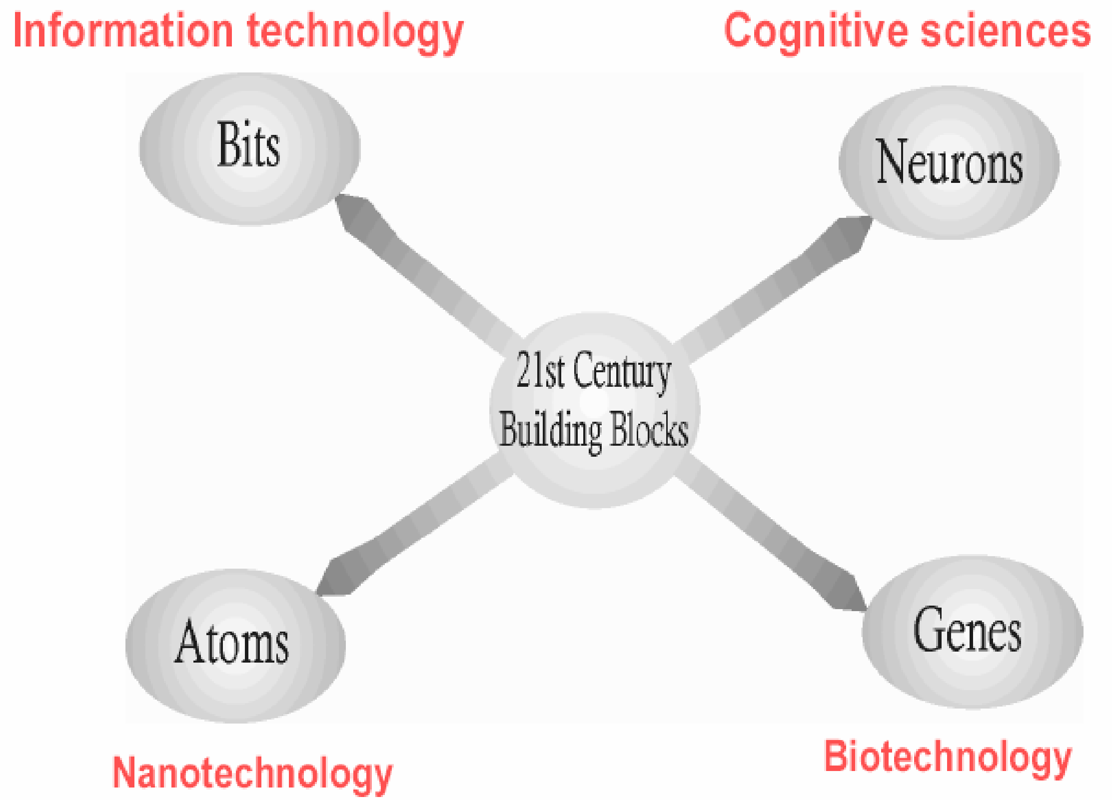
A.D. Maynard (Nov 7, 2005) “Engineered Nanomaterials: Measurement in the Occupational Setting”

Figure 4. Projected movement of nanotechnology.

Source: E. Michelson presentation, September 15, 2005; timeline adapted from M. Roco, NSF.

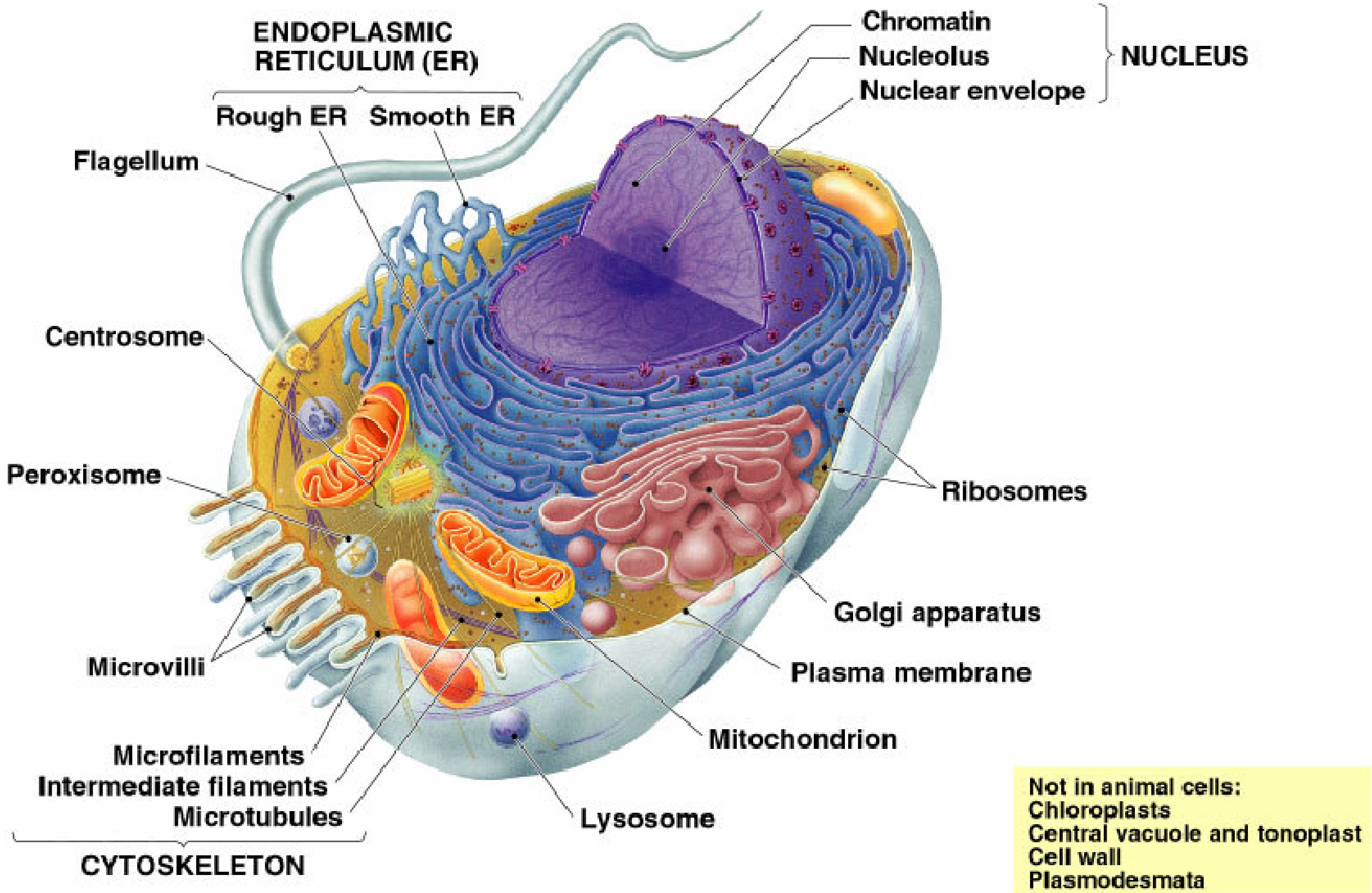






M.C. Roco (April 22, 2004) “The Emergence & Policy Implications of Convegring New Technologies”

B. Evolution of the Eukaryotic Cell (Most texts have detailed pictures of the organelles)



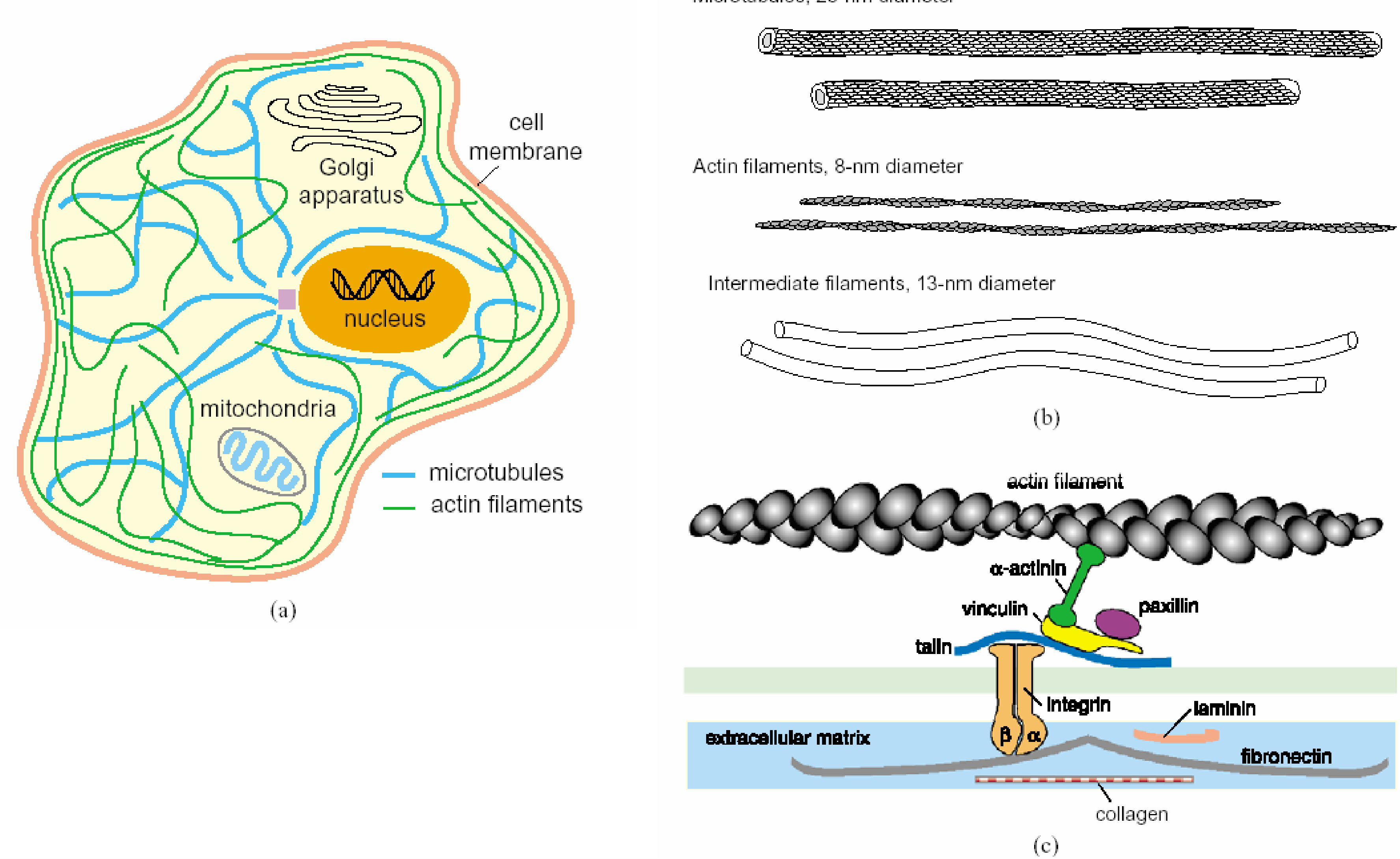


Fig. 2. (a) With an average size of 10–30 μm, an animal cell consists of a cytoskeleton wrapped by the plasma membrane, and a nucleus surrounded by the cytoplasm containing mitochondria, Golgi apparatus, and other organelles. (b) The cell cytoskeleton consists of microtubules, actin filaments, intermediate filaments and other binding proteins. (c) Adherent cells attached to the extracellular matrix (ECM) through the focal adhesion complex consisting of integrin and other binding molecules.

G. Bao (2002) "Mechanics of Biomolecules"
Journal of Mechanics and Physics of Solids

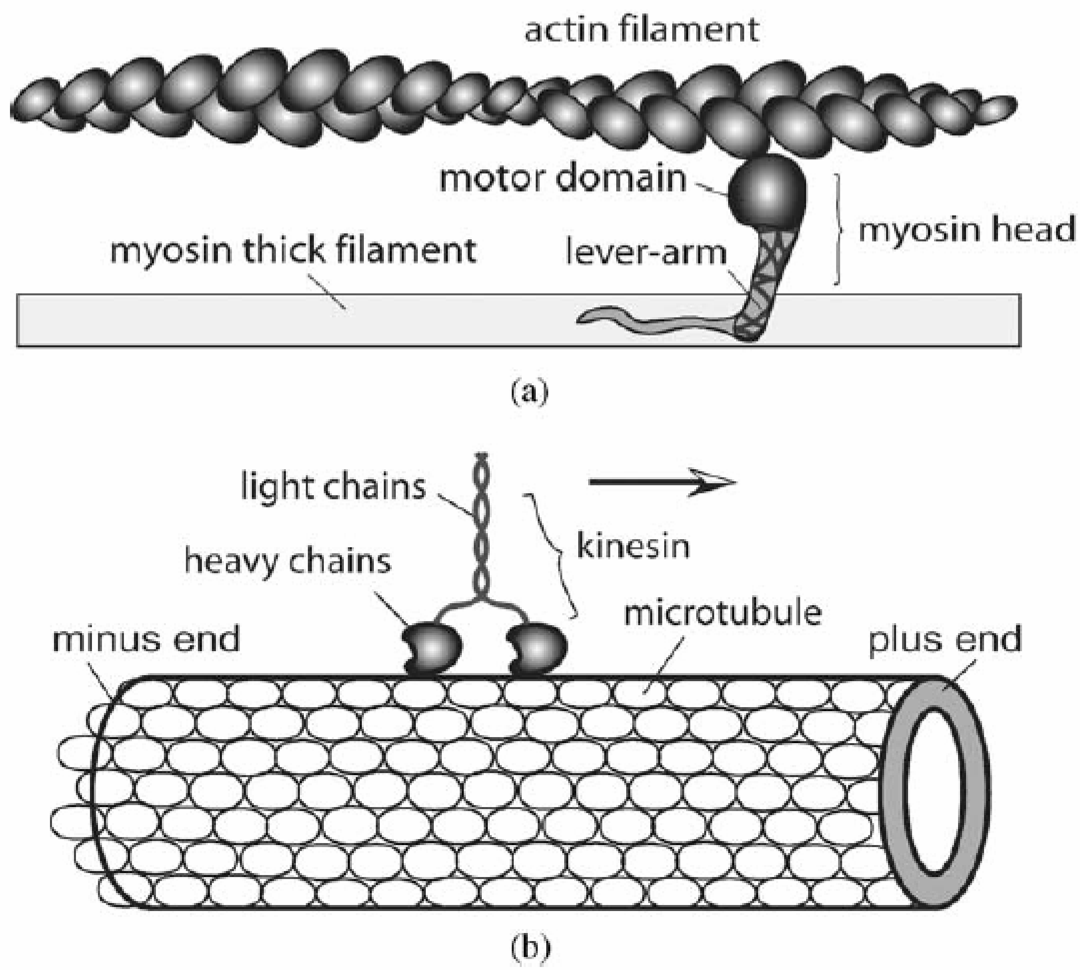
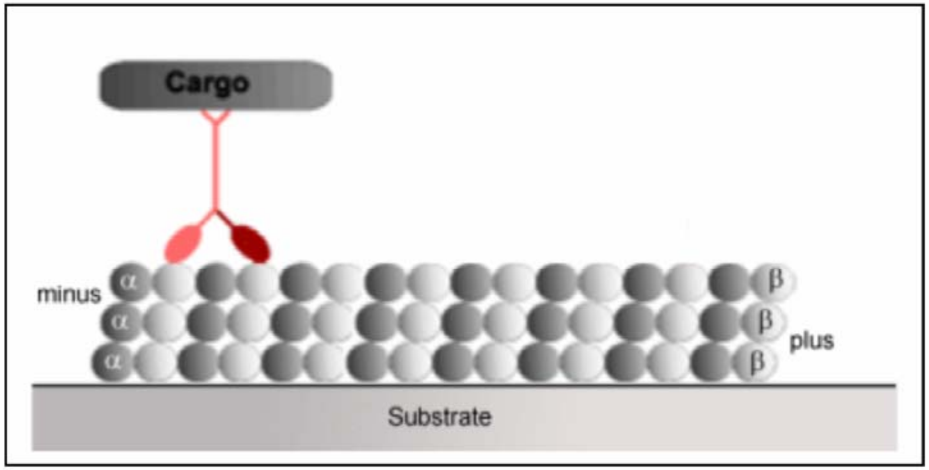


Fig. 11. Kinesin and myosin motors. (a) Upon ATP hydrolysis, myosin molecules generate sliding motion between antin and myosin thick filament through the swing of the lever arm. (b) Kinesin molecules 'walk' along microtubules by alternating the binding and unbinding of its two heavy chains to the microtubule.

“WALKING MOLECULES” THAT CARRY “CARGO”



Böhm KJ, Stracke E, Unger E: Mechanism of kinesin-dependent vesicle transport along a microtubule

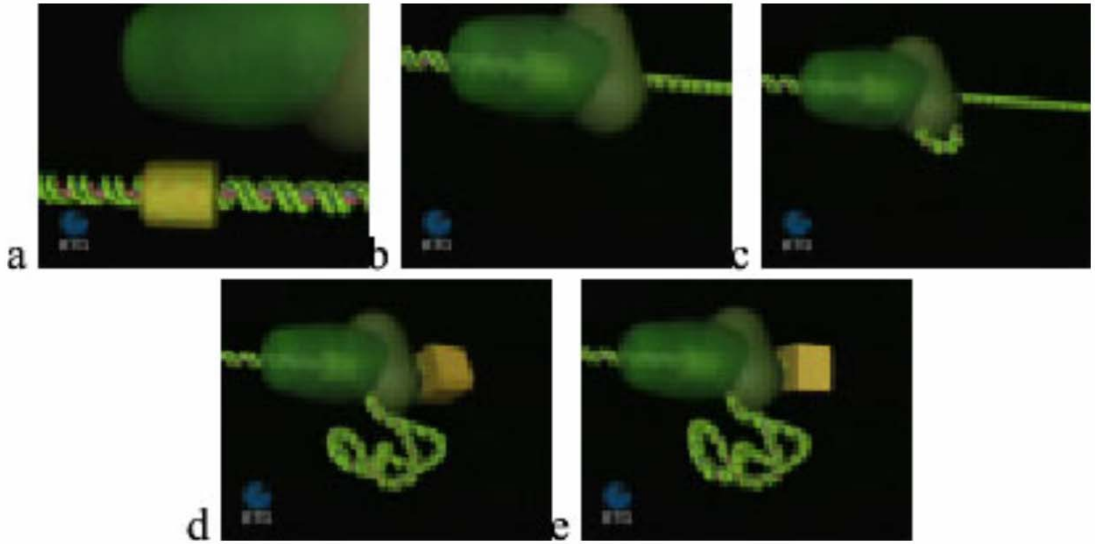
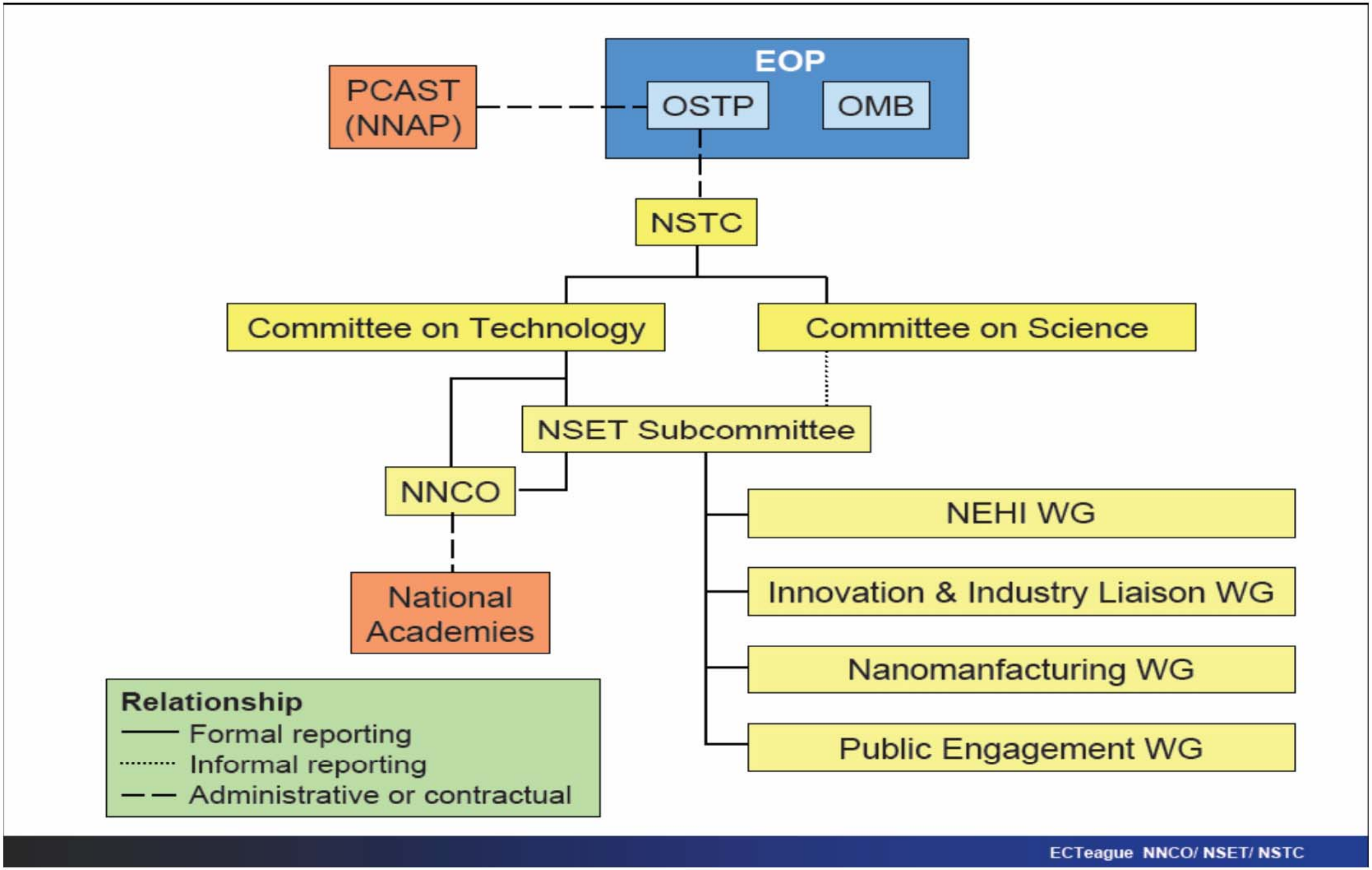


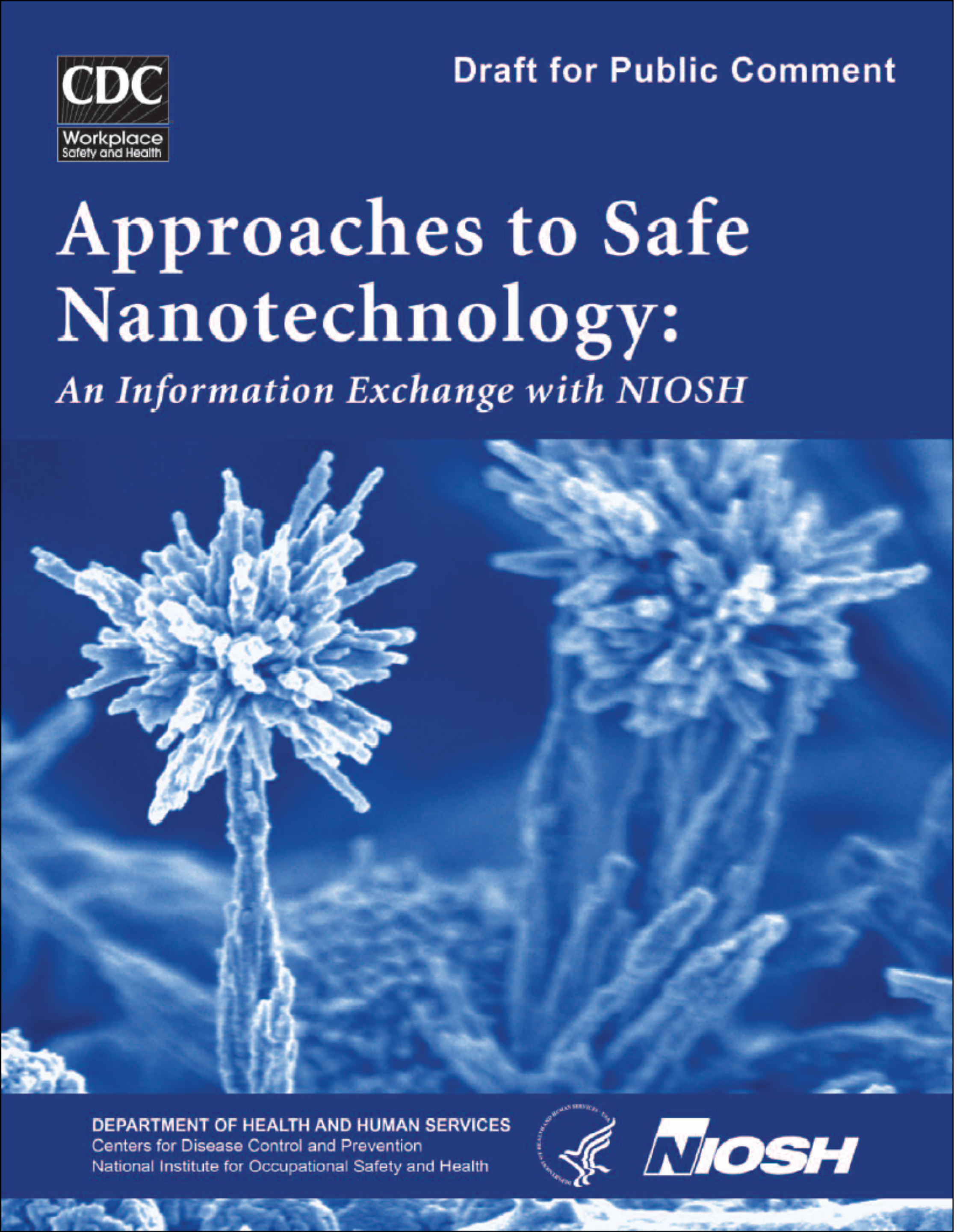
Fig. 1: Motor activity of type 1 R M Enzyme. (a) The yellow block represents the DNA-binding (recognition) site of the enzyme, which is represented by the green object approaching from the top of the screen and about to dock onto the recognition sequence. (b) The motor is bound to the DNA at the recognition site and begins to attach to adjacent DNA sequences. (c) The motor begins to translocate the adjacent DNA sequences through the motor/DNA complex, which remains tightly bound to the recognition sequence. (d) Translocation produces an expanding loop of positively supercoiled DNA. The motor follows the helical thread of the DNA resulting in spinning of the DNA end (illustrated by the rotation of the yellow cube). (e) When translocation reaches the end of the linear DNA it stops, resets and then the process begins again.

Biomolecular Motors A DARPA commissioned overview with highlights from the special session at Nanotech 2004, Boston, MA, USA; Srinivas Iyer1, Bart Romanowicz2 and Matthew Laudon2

http://www.nsti.org/Nanotech2004/

NATIONAL NANOTECHNOLOGY INITIATIVE (NNI)





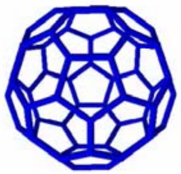
This document reviews what is currently known about nanoparticle toxicity and control, but it is only a starting point. The document serves as a request from NIOSH to occupational safety and health practitioners, researchers, product innovators and manufacturers, employers, workers, interest group members, and the general public to exchange information that will ensure that no worker suffers material impairment of safety or health as nanotechnology develops. Opportunities to provide feedback and information are available throughout this document.

http://www.cdc.gov/niosh/topics/nanotech/safenano/pdfs/approaches_to_safe_nanotechnology_28november2006_updated.pdf

EPA 100/B-07/001
February 2007

U.S. Environmental Protection Agency

Nanotechnology White Paper



Prepared for the U.S. Environmental Protection Agency by members of the Nanotechnology Workgroup, a group of EPA's Science Policy Council

Science Policy Council
U.S. Environmental Protection Agency
Washington, DC 20460

http://www.epa.gov/osa/pdfs/nanotech/epa-nanotechnology-white-paper-final-february-2007.pdf

The Nanotechnology White Paper provides:

1. A basic description of nanotechnology
2. Information on why EPA is interested in nanotechnology
3. Potential environmental benefits of nanotechnology
4. Risk assessment issues specific to nanotechnology
5. A discussion of responsible development of nanotechnology and the EPA's statutory mandates
6. An extensive review of research needs for both environmental applications and implications of nanotechnology
7. Staff recommendations for addressing science issues and research needs, and includes prioritized research needs within most risk assessment topic areas (e.g., human health effects research, fate and transport research)
8. An appendix that contains a description of EPA's framework for nanotechnology research, which outlines how EPA will strategically focus its own research program to provide key information on potential environmental impacts from human or ecological exposure to nanomaterials in a manner that complements other federal, academic, and private-sector research activities.
9. Collaboration with other researchers is a major focus of the paper

International Committee on Nanotechnology (ICON)
Nanotech Survey

- Environmental Health and Safety Program "Nano-specific"
- Engineering Controls
- Personal Protective Equipment and Clothing (PPE)
- Beliefs about Impediments to Health & Safety Management
- Waste Management of Nanomaterials
- Monitoring the Work Environment for Nanoparticles
- Attitudes towards Risk of Nanomaterials Handled
- Methods for Determining Risk of Nanomaterials
- Toxicity Testing
- Product Stewardship

NANOTECHNOLOGY – American Bar Association Analyses: Summary Table

ENVIRONMENTAL STATUTES	SUBJECT MATTER TERMINOLOGY	SCOPE OF STATUTORY AUTHORITY (this does not include the scope of exist regulations)
TSCA	nanomaterials as chemical substances and mixtures	EPA has authority to require health and environmental testing; collect production, health, and environmental information about nanomaterials; and promulgate rules regulating, and even prohibiting, the manufacture, processing, distribution, and use of nanomaterials.
CERCLA	***nanomaterials***	EPA has the ability to cope with the unanticipated adverse consequences of nanomaterials and ***previously accepted practices***
RCRA	***nanoscale materials, nanoscale constituents, nanoscale waste materials***	EPA already has expansive authority under RCRA to regulate ***discarded wastes that might include*** nanoscale materials
CAA	nanoparticles	Current CAA program already contains sufficient authority to adequately address nanoparticles
CWA	nanoparticles	EPA has the authority to regulate nanoparticles

TSCA

Proposed Draft Nanotechnology Program

- Engineering Controls
- Worker Training and Work Practices
- Hazardous Communication, Product Labeling and Customer Training
- Waste and Release Management (including spills)
- Personal Protective Equipment (PPE): respirators and personal protective clothing (e.g., gloves)

<u>City of Berkeley, CA</u>

[December 2006]

Section 15.12.050 Quantities ***<u>requiring disclosure</u>***.

A. Except as provided in the following subsections of this section, each handler who handles the following aggregate quantities of all hazardous materials and wastes at any time during a year shall disclose all such handling: 500 pounds or more of all solid hazardous materials and wastes; 55 gallons or more of all liquid hazardous materials and wastes; or 200 cubic feet or more at standard temperature and pressure of all gaseous hazardous materials.

B. Hazardous materials contained solely in consumer products packaged for distribution to, and use by, the general public shall be exempt from disclosure under this chapter unless the hazardous materials manager has notified the handler in writing that the handling of certain quantities of specified consumer products requires disclosure under this chapter in response to health and safety concerns.

C. The following disclosure requirements shall apply in addition to those in subsections A and B of this section:

****

7. All *<u>manufactured nanoparticles</u>*, defined as a particle with *<u>one axis less than 100 nanometers</u>* in length, shall be reported in the disclosure plan.

(Ord. 6960-NS § 2 (part), 2006: Ord. 6824-NS § 3, 2004)

City of Berkeley, CA

Section 15.12.040 Filing of *disclosure information*.

I. All facilities that *manufacture or use* manufactured *nanoparticles* shall submit a separate *written disclosure* of the

current *toxicology* of the materials reported, to the extent known, and

how the *facility* will

safely handle,

monitor,

contain,

dispose,

track inventory,

prevent releases and

mitigate such materials.

(Ord. 6960-NS § 1 (part), 2006: Ord. 6824-NS § 3, 2004)

WEB SITE AVAILABLE DOCUEMENTS

1) NIOSH, Approaches to Safe Nanotechnology: An Information Exchange with NIOSH
http://www.cdc.gov/niosh/topics/nanotech/nano _exchange.html

2) Science Policy Council Science Policy Council U.S. Environmental Protection Agency (2005) **FINAL - Nanotechnology White Paper** http://www.epa.gov/osa/nanotech.htm

STOP

NASA HEADQUARTERS

OFFICE OF INSTITUTIONS & MANAGEMENT

OFFICE OF INFRASTRUCTURE & ADMINSTRATION

NANOTECHNOLOGY CONTACT PERSONS:

1) Bill Brodt: 202-358-1117, wbrodt@nasa.gov

(Facilities and occupational safety & health aspects – past experience at National Institutes of Health)

2) Sam Higuchi: 202-358-0149, shiguchi@nasa.gov

(Environmental health aspects and policy issues – past experience includes conducting "acute bio-assay" toxicology experiments at U.S. Environmental Protection Agency's Laboratory as a guest research investigator)

D. Control Band Measures

Review the data gathered and identify the chemicals by one of the Bands below. The list of Bands is not exhaustive and you should use best judgment for your reporting.

List the control measures adopted or proposed to be adopted that are commensurate with the Band level you have identified for the nanoscale materials. If you intend to adopt control levels in the future, please indicate the
timeline for adopting such control measures.

Band 1: Low potential toxicity and no exposure pathway. Little or no control measures.
Band 2: Moderate potential toxicity and exposure pathways. Moderate levels of control measures
Band 3: High potential for toxicity and possible exposure pathways. High levels of control measures.
Band 4: Unknown toxicity and possible exposure pathways. High levels of controls measures.

I. ENGINEERING CONTROLS

Literature Review Key Information Summary

1. For most processes and jobs, control of airborne exposure to nanoparticles can be accomplished using a wide variety of engineering control techniques similar to those used in reducing exposures to general aerosols (NIOSH 2006, p. 22)

2. Current knowledge indicates that a well-designed exhaust ventilation system with a high-efficiency particulate air (HEPA) filter should effectively remove nanoparticles (NIOSH 2006, p. 22)

Questions

1. What worker activities may involve airborne dust containing the NM?
2. What engineering controls have been implemented for these activities?
3. What is the rationale for the selection of the engineering control? For air-purifying filters, do you have data on filter efficacy, and if so, what measurement techniques have been employed to detect the NM? Do you have data (e.g., personal sampling, area monitoring, etc.) on efficacy of other controls, and if so, and what measurement techniques have been employed to detect the NM?

<u>II. WORKER TRAINING/ WORK PRACTICES</u>

Literature Review Key Information Summary

1. Hazard information on common materials that are being manufactured in the nanometer range (e.g., TiO_2) should be considered as a starting point in developing work practices (NIOSH 2006, p. 14)

2. Incorporating good work practices in a risk management program helps minimize worker exposure to nanomaterials; examples include (NIOSH 2006, p. 22):

a. Cleaning work areas at the end of each work shift (at a minimum) using HEPA vacuum pickup and wet wiping methods. Dry sweeping or air hoses should not be used to clean work areas. Cleanup and disposal should be conducted in a manner that prevents worker contact with wastes and complies with all applicable Federal and State, and local regulations.

b. Preventing the storage and consumption of food or beverages in workplaces where nanomaterials are handled.

c. Providing hand-washing facilities and encouraging workers to use them before eating, smoking, or leaving the worksite.

d. Providing facilities for showering and changing clothes to prevent the inadvertent contamination of other areas (including take-home) caused by the transfer of nanoparticles on clothing and skin.

3. Regular training on respirators, including OSHA guidelines for voluntary use of respirators [29 CFR 1910.34 Appendix D] (NIOSH 2006, p. 24)

Questions

1. What worker training specific to the NM do you provide?
2. What are your work practices (include those mentioned above) for handling NMs at your site(s)?

III. HAZARD COMMUNICATION/ PRODUCT LABELING/ CUSTOMER TRAINING

Literature Review Key Information Summary

1. No NM-specific information for hazard communication (haz-comm), product labeling, or customer training was found in the limited literature search.

2. There are many uncertainties as to whether the unique properties of nanomaterials (which underpin their commercial potential) also pose occupational health risks (NIOSH 2006, p. 6).

3. Although insufficient information exists to predict the fire and explosion risk associated with nanoscale powders, nanoscale combustible material could present a higher risk than coarser material of similar quantity given its unique properties (NIOSH 2006, p. 12).

4. Depending on their composition and structure, some nanomaterials may initiate catalytic reactions and increase their fire and explosion potential that would not otherwise be anticipated from their chemical composition alone (NIOSH 2006, p. 13).

Questions

1. What are your approaches to haz-comm, product labeling, and customer training for the NM?
2. What information do you provide in your MSDS for the NM?
3. What information specific to the NMs do you include on the product labels?
4. Do you institute any special customer training for NMs?

IV. WASTE AND RELEASE MANAGEMENT (including spills)

Literature Review Key Information Summary

1. Follow any existing federal, state, and local regulations

2. No specific guidance is available on cleaning up nanomaterial spills; consider potential for exposure during cleanup (e.g., re-aerosolization, etc.) (NIOSH 2006, pp. 25, 30)

3. Collection of all NM waste materials for disposal in compliance with the site-specific Hazardous Waste Management Plan (Texas A&M, p. 6)

Questions

1. What waste streams and other releases (include all day-to-day and emergency response wastes and releases to all media, including fugitive dust emissions; equipment cleaning; emptied transport containers such as bags or drums; used respirator cartridges, HEPA filers, or gloves; etc.) may contain the NM?
2. What release controls and waste management practices have been implemented for these wastes and other releases? Do you dispose of any wastes as hazardous wastes? Do you treat any waste or release streams containing NMs on your site?
3. What is the rationale for the selection of the controls or practices? Where applicable, do you have data to determine whether the controls or practices (on-site or off-site) are effective, and if so, what measurement techniques have been employed to detect the NM in airspace, water, or other environmental samples?

V. PERSONAL PROTECTIVE EQUIPMENT (PPE)

A. RESPIRATORS

Literature Review Key Information Summary (all bullets below from NIOSH 2005, pp. 23-25)

1. Respirators may be necessary when other controls do not keep an airborne contaminant below a regulatory limit or internal control target

2. Decision on respirator should be based on a combination of professional judgment and results of hazard assessment and risk management practices

3. Effectiveness of controls can be evaluated using measurement techniques described in Exposure Assessment and Characterization (section of NIOSH 2006)

4. To assist respirator users, NIOSH has published the document NIOSH Respirator Selection Logic (see www.cdc.gov/niosh/docs/2005-100/default.html)

5. Preliminary studies indicate that NIOSH certified respirators should provide the expected levels of protection if properly selected and fit tested (note: The most penetrating particle size range for a given respirator can vary based on the type of filter media employed and the condition of the respirator (For example, the most penetrating particle size for N95 respirators containing electrostatically charged filter media can range from 50-100 nm to 30-70 nm.)

Questions

1. What worker activities may involve airborne particulates containing the NM?
2. What respiratory protection has been implemented for these activities?
3. What is the rationale for the selection of the respirator? For air-purifying respirators, do you have data on respirator cartridge efficacy?
4. Has an internal exposure control target been determined for this NM? If so, what are the target and the rationale for the target? Do you have data (e.g., personal sampling, etc.) to determine whether the target has been met, and if so, and what measurement techniques have been employed to detect the NM?

B. PERSONAL PROTECTIVE CLOTHING (e.g., gloves, etc.)

Literature Review Key Information Summary

1. No guidelines on selection for the prevention of dermal exposure to nanoparticles are available (NIOSH 2006, p. 23)

2. Penetration efficiencies for nanoparticles have not been studied (NIOSH 2005, pp. 22-23)

3. Existing clothing standards already incorporate testing with nanometer-sized particles (e.g., ASTM F1671-03 for bloodborne pathogen penetration specifies use of a 27-nm bacteriophage) provide some indication of effectiveness of protective clothing with regard to nanoparticles (NIOSH 2006, p. 23)

4. No NM-specific information for eye protection was found in the limited literature search.

Questions

1. What worker activities may involve exposure to skin (dermal exposure) and to eyes to the NM or to mixtures containing the NM? What are the physical state(s) of the NM or mixtures containing the NM (for mixtures, include NM concentration)?
2. What skin or eye protection has been implemented for these activities?
3. What is the rationale for the selection of the protective clothing? For gloves, do you have data on efficacy toward NMs, and if so, what measurement techniques have been employed to detect the NM?

CITY OF BEREKELEY: Introduction to Manufactured Nanoscale Material Health & Safety Disclosure For the reporting period of June 1, 2007-June 2, 2008

Due June 1, 2007

A. General Information

1. Provide a cover letter signed by senior member of the staff indicating the information is accurate no later than June 1, 2007.
2. Fill out the company information (OES Form 2730) unless you have already submitted an HMBP.
3. Provide the common name of the nanoscale material or class of materials.
4. Where present, provide the Chemical Abstract Service (CAS) number. For mixtures, enter the CAS
number of the individual chemicals. If there is no CAS number assigned to this material please indicate.
5. Provide the average and the maximum daily amount of the material stored onsite at any on time during the year. Specify the units used (use metric units where possible).
6. Provide the physicochemical properties of the nanoscale material material. Include available information about the following: chemical form (e.g., solid, liquid), purity, particle dimensions, prediction of surface area with approximate mass, shape, aggregation potential, water solubility, flammability, flash point, and reactivity.
7. Provide the source of the material if it is not produced on site. Please provide the address and contact information for the site from which the material was obtained
8. Indicate the type of substrate used if any and any relevant toxicological information that may be important about the substrate.
9. Indicate the use within the site, intended downstream use, and information about the benefits of the applications.

B. Toxicology

10. Provide toxicological information about the nanoscale material. If available, include information regarding inhalation toxicity, dermal penetration and/or toxicity, and oral toxicity, mutagenicity/ genotoxicity, and reproductive toxicity.
11. Provide ecological information about the nanoscale material, which may include: effects on organisms, degredation/ biopersistance, and bioaccumulation potential.

CITY OF BEREKELEY: Introduction to Manufactured Nanoscale Material Health & Safety Disclosure For the reporting period of June 1, 2007-June 2, 2008

Due June 1, 2007

C. Occupational and Environmental Protection

12. Provide safe handling information for the nanoscale material
13. Provide information about the potential exposure pathways and likelihood of exposure via these pathways.
14. Provide a list of personal protective equipment (PPE) used in production and handling of the nanoscale equipment
15. Provide descriptions of engineering and administrative controls, such as local exhaust ventilation or job rotation, that are used to reduce employee exposures.
16. Provide a training plan for employees who may come into contact with nanoscale material. Include safe handling procedures, release prevention, release mitigation and disposal methods
17. Provide the clean up methods and procedures for accidental spills or releases
18. Provide the container type that the nanoscale material is stored in. Please indicate if the material is stored in more than one type of container.
19. Provide a site map indicating safety equipment, spill mitigation equipment, engineering control equipment, storage areas, and process areas.

CITY OF BEREKELEY: Introduction to Manufactured Nanoscale Material Health & Safety Disclosure For the reporting period of June 1, 2007-June 2, 2008

Due June 1, 2007

IMPORTANT NOTES:

- Where information is not available, please indicate this in the disclosure.
- For the purpose of efficiency you may refer to multiple manufactured nanoscale material as a single category in your submittal if they show similar behavior.
- Trade Secret: Please print “TRADE SECRET” on the top right of each page of the disclosure, which is subject to trade secret clause per California Health and Safety Code Section 25538. Trade secret status does not preclude you from submitting required information.
- If you have an internal procedure that addresses all the analyses indicated below, you can make a request to TMD to submit your report using your individual process.

WEB SITES

- http:// www.nano.gov/
- http:// es.epa.gov/ncer/nano/
- http:// www.fda.gov/nanotechnology/
- http:// www.cdc.gov/niosh/topics/nanotech/
- http://www.becon2.nih.gov/nano.htm
- http://www.ostp.gov/pcast/pcast.html
- https://intranet.dodmeritinfo.net/index.cfm
- http://www.aepi.army.mil/
- http://www.wilsoncenter.org/index.cfm
- http://www.merid.org/nanodev/
- http://www.smalltimes.com/
- http://web.mit.edu/ISN/
- Several Others